Methods for Conducting Cognitive Task Analysis for a Decision Making Task

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Cognitive task analysis (CTA) improves traditional task analysis procedures by analyzing the thought processes of performers while they complete a task. For this report, we have selected several of the measures for which we found differences in experts and novices and have detailed the procedures for using these methods to conduct a CTA for domains which involve critical decision making tasks in naturalistic settings. The cognitive task analysis methods that we describe are: (1) development of a task process model, (2) development of an information flow model, (3) misconceptions analysis, and (4) structural knowledge analysis. For each of these methods we describe how information is gathered (knowledge elicitation), how it is represented in a format that can be later used in designing training (knowledge representation), and how the knowledge can be used in developing training.

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Foreword

This technical note describes work conducted as part of the Navy Personnel Research and Development Center's Complex Cognitive Skills (COPE) project. The COPE project is part of the Navy Exploratory Development Program, Technology Program Element 0602233N, Work Unit RM33T23.08, sponsored by the Office of Naval Research.

The first part of the COPE project investigated methods for analyzing cognitive skills in technical tasks; this work was reported in a paper submitted for publication (Randel, Pugh, & Reed, 1995). For this technical note, we have selected several of the methods that revealed expert/novice differences and demonstrated how these methods could be used to conduct a cognitive task analysis (CTA) in domains involving decision making tasks.

The authors wish to acknowledge the contribution of John S. Schuler for his initial work and ideas on the information flow model.

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Summary

Background

Analysis of the cognitive factors involved in a complex task should provide improved training and assessment. Cognitive task analysis (CTA) enhances traditional task analysis procedures by analyzing the thought processes of performers while they complete a task. One way of identifying the cognitive skills needed to perform a task well is to compare expert with novice understanding of the task. When experts are found to differ from novices on the cognitive aspects of a task, this input can be used to improve training design. Earlier work for this project examined the Electronic Warfare (EW) operator task for differences between novices and experts in several areas of cognitive functioning. Many of these measures revealed differences between novices and experts.

Purpose

The purpose of this report is to provide a guide to those who wish to conduct a cognitive task analysis of a technical task that emphasizes decision making. It is meant for those who are familiar with the concept of task analysis and wish to include cognitive aspects of their task in this analysis. It does not replace traditional task analysis, but adds the cognitive components to it.

Method and Results

We have selected several of the measures for which we found differences between experts and novices and have detailed the procedures for using these methods to conduct a CTA for domains which involve critical decision making tasks in naturalistic settings. The cognitive task analysis methods that we describe are (1) development of a task process model, (2) development of an information flow model, (3) misconceptions analysis, and (4) structural knowledge analysis.

For each of these methods we describe how information is gathered (knowledge elicitation), how it is represented in a format that can be later used in designing training (knowledge representation), and how the knowledge can be used in developing training.

Conclusions

The methods described here are appropriate for conducting a cognitive task analysis for a complex decision making task. Any of the methods could be used individually or in combination.

Recommendations

We recommend that the cognitive task analysis methods described here be used in developing or revising instruction for complex decision making tasks. These methods could be used in conjunction with traditional task analysis.

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Introduction

Background

The modern work environment requires skilled operators to perform tasks on complex systems in an efficient, cost-effective, and safe manner. Operator training for such tasks as those performed by air traffic controllers, radar operators, and electronic warfare technicians often emphasize the learning of facts and procedures. Recent developments in cognitive science indicate that an analysis of the cognitive factors involved in a skill should provide improved training and assessment (DuBois & Shalin, 1995; Gordon, Schmierer, & Gill, 1993; Hall, Gott, & Pokorny, 1990). To understand how an operator conceptualizes a task, we need to use methods which reveal not only the behaviors that are being performed but also the decisions that are made and the decision makers' reasons for these actions.

The traditional method for analyzing a task is to decompose it into subtasks, skills, and knowledge. Cognitive task analysis (CTA) improves this process by including an analysis of the thought processes of performers while they complete a task. One of the earliest attempts to perform CTA (Greeno, 1976) demonstrated the use of procedural representations and semantic networks for a cognitive task analysis of topics taught in the classroom. More recently, others have applied cognitive analyses to tasks performed on the job; for example, the strategic knowledge used in solving a troubleshooting task was considered along with declarative and procedural knowledge (Hall et al., 1990). For analyzing a complex operator task involving decision making, no adequate CTA method was available.

Although the methods being introduced in this paper are intended to be relatively simple and economical, it should be recognized that cognitive task analysis can raise the cost of task analysis so the cost-benefit of such analysis should be considered. Because thorough cognitive analysis may require the skills of highly trained professionals at its present stage of development (Lesgold et al., 1986; Modrick, 1992; Redding, 1989), consideration should be given to the appropriateness of using cognitive task analysis for any task. Gott (1994) suggested that CTA should be used when a task is complex, when it is difficult to learn because action goes on in the head of a performer, and when tasks are not presequenced; that is, the task is dynamic, unstable, and ill-structured. These requirements describe the decision making task of the electronic warfare technician (EW).

We conducted an experimental investigation of methods for analyzing cognitive skills in a technical task involving decision making (Randel, Pugh, & Reed, 1995). One way of identifying the cognitive skills needed to perform a task well is to compare expert with novice understanding of the task. Experts and novices were identified on the basis of their performance on a technical task as measured by a performance assessment instrument. The operator task performed by the electronic warfare technician (EW) was examined for expert-novice differences in several areas of cognitive functioning.

EW operators working on ships use computer automated equipment to help detect and identify potentially hostile radar systems. The EW operators extract clues as to the possible threat of a radar by observing on a display screen a diagram of the positions of all the emitters in the area, by looking at the computer readout of certain parameters of the signal, and by listening to an auditory

1

representation of the signal. Along with the computer data, the EW uses information gathered from other watchstanders aboard ship and published data to make his assessment of the situation. The EW informs higher authority of the nature of threat signals and recommends appropriate actions including countermeasures. Further details on the EW job and experimental study of EW expert and novice differences can be found in Randel et al. (1995). The present technical note takes some of the cognitive task analysis techniques investigated and shows how they can be used to analyze a technical task. Here, the EW is used as an example only; it is not necessary to understand the EW job completely to follow these procedures.

Purpose

The purpose of this report is to provide a guide to those who wish to conduct a cognitive task analysis of a technical task that emphasizes decision making. It is meant for those who are familiar with the concept of task analysis and wish to include cognitive aspects of their task in this analysis. It does not replace traditional task analysis but adds the cognitive components to it.

For this report, we have selected several of the measures for which we found differences between experts and novices and which would generalize to other domains. We have detailed the procedures for using these methods to conduct a CTA for domains which involve critical decision making tasks in naturalistic settings. We have taken the methods investigated experimentally and indicated how they can be used in domains other than the EW.

Method and Results

The methods that we will describe here are:

1. Development of a task process model.

2. Development of an information flow model.

3. Misconceptions analysis.

4. Structural knowledge analysis.

For each of these methods we will indicate (1) how knowledge is elicited, (2) how it is represented, and (3) how it can be used in training.

Development of a Task Process Model

One aspect of cognitive task analysis is the development of a model of a task that requires decision making. By model we mean a graphic or schematic representation of the task. The model is developed from observation and questioning of the task performers either while they are performing the task, or, if the task would be disrupted by the questioning, after the task has been completed. The objective is to develop a model of the task that can be used to organize training. Each part of the model can be taught in training and anything taught can be related back to the task model. Training that is organized around a task will be seen as relevant to the actual job to be performed and as a topic is taught, its use in the actual job can be seen.

In the following three sections on the development of a task process model, we will first discuss how information about task performance is obtained to build the model (knowledge elicitation), and then explain the form in which the knowledge is documented (knowledge representation). Finally, we consider how this model can be applied to training.

Knowledge Elicitation for a Task Process Model

The purpose of knowledge elicitation is to gather information on how the task is performed so that this information can be represented as a model. The following steps explain how to gather this information.

1. **Obtain an understanding of the job.** The more complex the job, the more you will need to know about it to understand what a task performer or subject matter expert (SME) is telling you during questioning in an interview. This understanding can be achieved in a number of ways.

   a. Collect and analyze documentation relevant to the task to get an overview of the job being performed. Documentation might include: training documents, fleet training requirements, and occupational standards.

   b. Observe any available training exercises or actual job performance.

   c. List the major high level tasks (e.g. for the EW, four major high level tasks were identified: emitter identification, communication, countermeasures, system operation).

2. **Select subject matter experts (SMEs).** If possible, select SMEs on the basis of an operational performance measure. If a performance measure is available, both experts and novices could be studied for comparison.

3. **Conduct interviews.** The interviews have two purposes: (a) to develop a model of the task, and (b) to identify critical components of the decision making process. The output from both of these elements can be used in the design and development of training. The interviews should be conducted in two stages; the first stage allows you to develop a preliminary model of the task which is then analyzed for completeness. From this analysis, questions are developed for the second stage interview. The second stage interview ensures the accuracy of the preliminary model and verifies the decision information collected. The second stage interview also enables elaboration of the task model to an appropriate size (usually no more than two pages) that can be used in training.

   a. **Stage 1 Interview.** The purpose of this interview is to develop a preliminary model of the task and to identify areas in the model where additional information is needed. This interview can be conducted after a simulation exercise, after a training exercise, or, if these are not available, from the description of a critical incident that has occurred in the past. If a simulation exercise is used, the simulation should contain some incidents where a moderately difficult decision must be made. It should also ideally contain some of the usual elements of incidents that would normally take place during a period of job performance. Approximately three to five interviewees should be obtained for this stage.

Critical Incident. Get interviewees to describe a critical incident from the simulation or from their experience. A critical incident should involve a situation where error was likely or did in fact occur. Use the Critical Incident Interview Guide (Appendix A), which is based on the work on naturalistic decision making of Klein and associates (Calderwood, Crandall, & Klein (1987). For any decision point that is probed, obtain information on the cues involved, errors made, missing data, differences between novices and experts, knowledge used, decision options (if any), and rules of thumb. If actual experience of interviewee(s) is not appropriate, then probe for a simulation exercise that was found particularly challenging during training. Probe for the important tasks that are performed on the watch and which contribute to decision making or problem solving.

Preliminary Model. From this interview and the documentation analyzed, draw a preliminary task process model in the form of a flowchart of how each interviewee conceives the job. It is particularly important to include the decision points. Figure 1 is an example of a simple task process model, with only one decision point (diamond shape) shown. Your preliminary model may contain more steps than this.

Figure 1. Preliminary task process model.
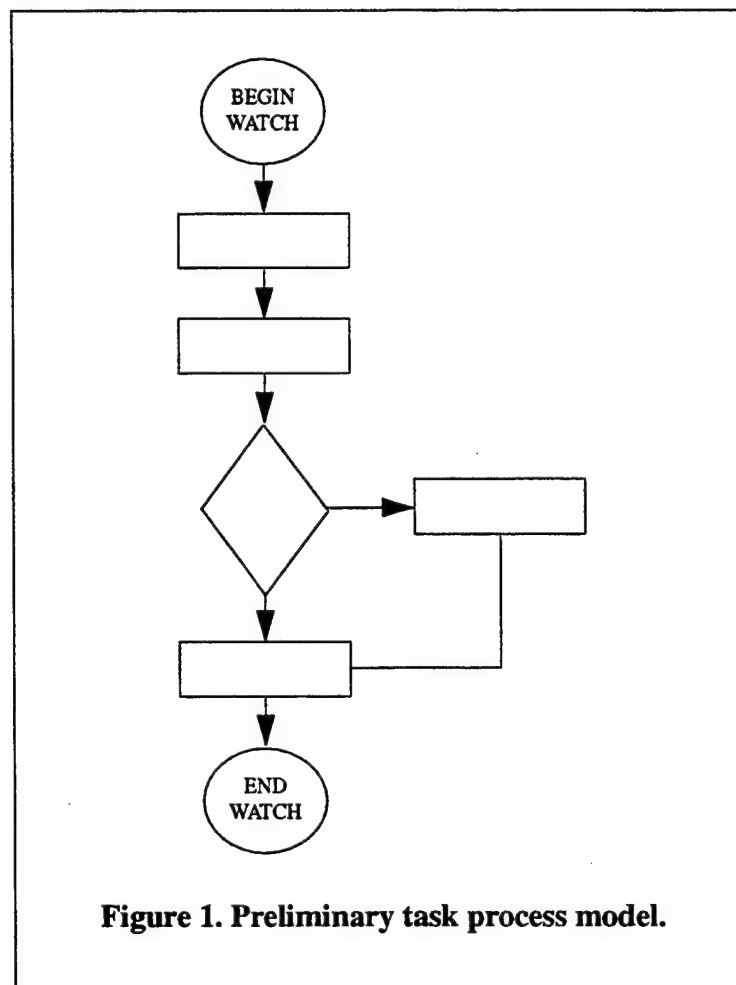
Composite Model. After you have completed a model for each individual, construct a preliminary composite model based on the elements which are mentioned most often. It may be necessary to include some elements which are not mentioned frequently, but which were stated to

be important. This preliminary model will help you understand how well you comprehend the tasks. Note where you are uncertain of what is occurring in the performance of the task, and write questions to ask about these areas in the Stage 2 interview.

b. **Stage 2 Interview**. These interviews would optimally involve an additional 8-20 interviewees, with some novices as well as experts, if possible. These interviews make use of material gathered during Stage 1 interviews. Additional questions will have been created to answer any uncertainties about the task process model of the task. An example of such questions used in analyzing the EW task are given in Appendix B. Present the scenario followed by the interview, using the Critical Incident Interview Guide.

Knowledge Representation for a Task Process Model

The knowledge obtained by this method will be represented as a model of the task. For each individual interviewed in Stage 2, construct a model of the task the same way you did for the preliminary models. Use the information obtained from the new questions constructed from the first interviews and asked in Stage 2. Then construct a new composite model of the task for the experts. If novices were interviewed, a separate model could be constructed to contrast with the expert model.

An example of such a process task model is contained in Appendix C for the EW. It was kept to two pages because any greater detail at this time would make it too complex to be used to guide instruction. While the model is of necessity a simplified outline of the task to be performed, it could be further extended to include the elements that make up any of the boxes. Note that the first row of boxes in Appendix C displays five subtasks that need to be performed. The order of these five subtasks may vary depending on the situation, and this will need elaboration during instruction.

After the model is constructed it should be validated by presenting it to other knowledgeable SMEs such as instructors and people with recent experience on the task. On the basis of input from this group, the model may be modified. However, once modifications are made, the model should be again presented to additional SMEs to ensure there is agreement on the modifications.

Training

The knowledge represented by the task model can be used as an organizing framework to train people to perform the job. During instruction, any of the boxes could be expanded to greater detail. This model should not be considered static and can be modified as situations or preferences change. However, if it is displayed in a prominent place in the classroom, perhaps on a white board so it can be modified, each module of instruction can be related to the overall task.

If a novice model was constructed, differences between this model and the expert model could be contrasted. The novice model would indicate how the novice generally thinks about the task. The curriculum developer could use this information to determine how it differs from the expert and then attempt to bring the novice gradually to the more expert way of thinking.

On the basis of the expert model, realistic situations requiring difficult decision making could be developed to represent each of the decision areas in the model. Experts could be interviewed for

cases involving these situations, and these could then be used in training. Using the model as the basis for these situations could ensure that all important areas are covered.

Development of an Information Flow Model

In order to make informed decisions, it is necessary to gather information from a variety of sources, and it is often necessary to pass information on to others in the decision making process. Information flow refers to the process of gathering information, relating it to other information, and transmitting acquired information to appropriate recipients. To understand how the flow of information is conceptualized, the task performer can be asked to draw or diagram the path for information flow. Data from both experts and novices can be compared and used to guide training.

In the following three sections on the development of an information flow model, we will first discuss how the information flow model is obtained (knowledge elicitation), how the knowledge is documented (knowledge representation), and how this model can be applied to training.

Knowledge Elicitation for an Information Flow Model

To obtain data on a task performer's mental representation of information flow, present a specific instance in which information must be relayed and ask the respondent to diagram how information is communicated for this particular task. Tell them to use boxes for each person or position and arrows to indicate the direction of the information. For example, we asked the EW to diagram how information is communicated aboard ship and to the battle group once a new emitter is detected.

Knowledge Representation for an Information Flow Model

Taking the information flow models drawn by the individuals, construct a composite model based on the elements that are mentioned most often. Sometimes this will involve a judgment call if something is mentioned less frequently but its importance is emphasized. An example of a composite information flow model for the EW expert group is given in Figure 2. This example is given to show the type of diagram with boxes and arrows that might be used; for this discussion it is not necessary to understand each of these jobs.

The point of this diagram is to show to whom the worker communicates directly and indirectly. If a novice diagram is constructed, comparisons can be drawn between the novice and expert diagrams. In Figure 2, we see that the EW operator communicates directly to everyone in this diagram, even though his supervisor also communicates to many of these same people. The novice diagram showed that the novice relied on the supervisor for most of his communications and did not directly contact the other workers.

Figure 2. Composite information flow model for the EW expert group.
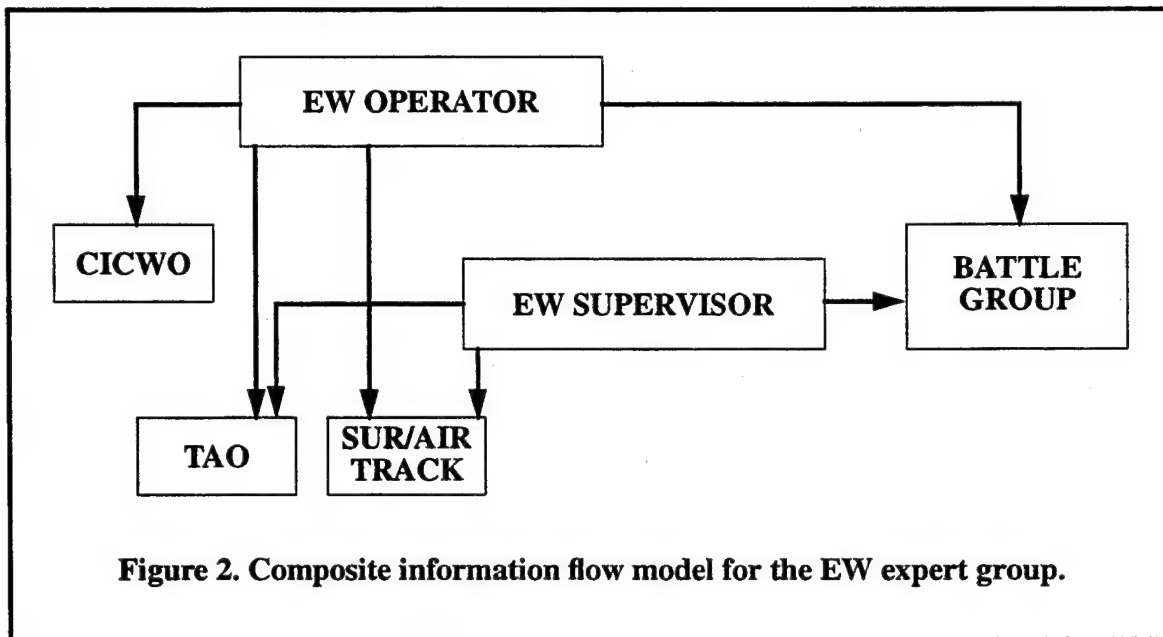
Training

Information flow maps for any job can be used to teach students who they should be communicating with to obtain and disseminate information. Using information flow maps to emphasize the need to seek information could improve communications in any job involving several players. In addition, these maps could be used to develop a computer simulation to practice selecting appropriate sources of information for different tactical situations.

For assessment purposes, information flow maps could be obtained from students at an appropriate point in their instruction. The maps the students draw can be compared to those obtained during the analysis phase of the program or those constructed by the instructors. Different maps may be drawn for different tasks or situations.

Misconceptions

Related to decision making, and perhaps imposing limits on it, are misconceptions that might be held in conceptualizing a task. Feltovich, Spiro, and Coulson (1989) studied the structure of complex ideas and the development of misconceptions in biomedicine. They describe a pattern of biomedical misunderstandings in which the interdependency of misconceptions and the oversimplification of concepts are two prominent features of misunderstandings.

It seems reasonable to look for the interdependency of misconceptions and also to look for cases of oversimplification on the part of operators--particularly in the novice operators. Larkin, McDermot, Simon, and Simon (1980) indicate that experts can see underlying causes because they can refer to the complex models they have stored. Obtaining comments and qualifying remarks from operators can help us understand what complex models aid them in their decisions.

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One way to study misconceptions is to examine the heuristics or rules of thumb that operators use in making decisions. Rules of thumb are often used by experts to represent knowledge about a task that novices can follow. A rule of thumb can be considered compiled knowledge of the expert presented in an integrated form. A problem could arise when the novice does not understand the boundary conditions of the rule or when it may not apply. Decision aids, of which rules of thumb could be considered an example, have been shown to be problematical when novice decision makers use aids based on expert-level representation (Ryder, Zachary, Zaklad, & Purcell, 1994).

In the following three sections, we describe a method for studying misconceptions in rules of thumb. We discuss how the information on misconceptions is obtained (knowledge elicitation), how the knowledge is documented (knowledge representation), and how this information can be applied to training.

Knowledge Elicitation for Misconceptions

To study misconceptions in rules of thumb, information about possible misconceptions is obtained through the following three steps.

1. **Prepare the list of rules**. While discussing decisions for the task process model, or independently in relation to a simulation or real event, obtain information on rules of thumb used in making the identified decision. With regard to the decision being discussed, ask what advice or rule of thumb the operator would give to someone standing beside him or her during a decision (see Appendix B, item 5f). You should try to have a list of about 12-15 rules which workers have said would be good rules to follow in realistic job situations. It would be ideal to obtain these rules from a range of operators from novice to expert.

When preparing the rules of thumb to be considered at the next stage in the interview, look for apparent contradictions. Often the contradictions will be subtle and not immediately obvious. For example, for the EW, the following pair of rules were included: (a) Don't report an emitter as a missile unless you are sure it's a missile; (b) better to call something a missile when it is not a missile than the other way around. There is an apparent conflict between (a) and (b); namely, don't report something as a missile unless you're sure, but if you're not sure then call something a missile. Be sure that you are aware of such contradictions, but do not pair them up on your list. Prepare the list of plausible rules, consolidating the inputs as appropriate.

2. **Interview operators on each rule**. Ask whether each rule is good to follow and ask operators to give reasons why the rules are good or bad. Note particularly the exceptions that they make, and also note the situations that they describe for the application of the rule. Experts often give important exceptions to rules, so it is important to note elaborations which tell when and how a rule is to be applied. These comments may provide the most important information.

3. **Question apparent contradictions**. When you prepared the list of rules you noted which rules were not in agreement. Consider the two rules that were given as an example above. If someone agrees that both of two contradictory rules are good to follow, then it is important to find out how such a contradiction should be resolved. For example, the subject may say that when you are uncertain that an emitter is a missile, that you should check with the watch supervisor first, or

that it should be reported as a missile but that the uncertainty should be reported also. Thus, exceptions and elaborations are very important.

You can compare experts and novices on the exceptions and elaborations they provide. Experts will often anticipate a conflict between rules and explain how they apply to different situations even before you point out particular contradictions. Experts tend to see the big picture, and so they will accept fewer contradictory pairs of rules than novices. Questioning experts on apparent contradictions can bring out the tacit knowledge that underlies expertise. Making use of this expertise will help to train students better and more quickly.

Knowledge Representation for Misconceptions

1. List the rules that are considered useful in making decisions. Include the elaborations and exceptions to the rules obtained in the interviews. Specific examples of situations should also be recorded.

2. If incompatible rules were found, list these also. Include explanations of the circumstance under which these rules would be used.

Training

The result of carefully preparing a list of rules of thumb and then probing these rules during interviews is that you have important information to guide the development of training. The rules themselves are guides to what workers actually use on the job. Making these rules explicit along with the elaborations and exceptions ensures that novice operators will know the boundary conditions of the rules that are often passed down to them on the job without these limitations being specified. Charness (1989) points out that the novice needs to be warned that the basic principles have side conditions attached. Problems of oversimplification can be prevented when exceptions and limitations are included with the rules. Examples of situations gathered in the interviews can be used to teach the rules in context, so that people are not confused on how to follow the various rules on the job.

Structural Knowledge

Structural knowledge refers to the organization of concepts within the memory system of an individual. Knowledge organization and the relationship of the elements in a subject-matter domain is one of the dimensions that may underlie the components of proficiency (Glaser, Lesgold, & Lajoie, 1987). Structural knowledge is not only essential to problem solving but also to recall and comprehension of information. Memory research indicates that information with some structure is remembered better than unstructured lists of information (Rumelhart, 1975; Thorndyke, 1977). As part of a cognitive task analysis, we would like to know how the important concepts in a domain are organized by experts, so that these concepts can be taught in their relationship to each other rather than as independent entities.

The first step in assessing structural knowledge is eliciting knowledge from an individual or group of individuals. Ratings of the similarity of concepts have been used to elicit knowledge in different subject-matter areas, and it is believed to be a method independent of the content domain,

reliable over time and across experts (Jonassen, Beissner, & Yacci, 1993). The next step, the analysis and representation of the data, is a process of inferring the psychological structure. These procedures are described below.

Eliciting Structural Knowledge

Obtain similarity ratings by asking individuals to rate the degree of similarity between pairs of concepts. This method identifies a group of important concepts and has the respondent rate the degree of similarity between each of the pairs of concepts.

1. Compile a list of the most important concepts in the domain. These concepts could relate to the entire domain, to a segment of it, or to a scenario. No more than 24 concepts should be used at one time because of the time it will take to compare each concept with the other concepts.

    a. Create a list of the important concepts from curriculum and instructor guides or from the terms identified as relevant to a scenario.

    b. Have two or three subject matter experts review the list to add missing concepts or to delete unimportant ones.

    c. If you have more that 24 concepts, have two to three subject matter experts rate the importance of each concept on the list from 0 (not important) to 3 (most important). Select from the more highly rated concepts. Repeat this procedure until the desired number of concepts is reached.

2. Using the selected concepts, create a randomized list of all possible pairs of the selected concepts.

    a. Using the following formula, you can determine the number of pairs:

$$\frac{x\,(x-1)}{2}$$

where x is the number of concepts used.

For example, if you have 24 selected concepts, you will produce 276 possible pairs.

$$\frac{24\,(24-1)}{2} = 276$$

    b. Produce a randomized list of all possible pairs. It would be helpful if you had a computer program that did this for you. Someone who knows some elementary computer programming should be able to do this.

3. Select a group of individuals who will rate the list of all possible pairs of the selected concepts. Depending on the level of expertise that you are interested in, you may select a group of experts, intermediate level individuals, and novices. For example, an expert rating may be created by selecting a group (2-5) of experts that are extremely knowledgeable with the subject matter. These are averaged in the program to produce the expert judgment.

4. Ask each respondent to rate the strength of the relationship between each pair of concepts by using a scale of 1-7 where 1 indicates a very weak relationship and 7 indicates a very strong relationship between the concepts. For 276 comparisons, it takes approximately one-half hour to complete the ratings of similarity of 24 concepts. Present a simple example of the procedure:

"Rate how closely the two concepts in each pair are related to each other."

Yellow Labrador--Cocker Spaniel   [may be rated a 7 (strong relationship)]

Yellow Labrador--Pen   [may be rated a 1 (weak relationship)]

Representing Structural Knowledge

Description and example. A Pathfinder Net (PFNet) is a graphic network in which concepts are represented inside nodes (rectangles) and the relationships between the concepts are depicted as links (lines) that connect the nodes (Schvaneveldt, 1990; Schvaneveldt et al., 1985). The links are given a value that reflects the strength of the relationship between the nodes. These values determine the length of the path from one concept to another. Using the procedures below, a PFNet can be produced from the data collected and described above.

Procedures. The procedure is automated by a group of computer programs known as Knowledge Network and Orientation Tool (KNOT) (Esposito, McDonald, Schvaneveldt, & Sitze, 1992). This program runs on the Macintosh computer. The process is as follows:

1. Set up a matrix data file from the obtained similarity ratings. Each point of intersection in the matrix indicates the respondent's rating of similarity between those two concepts.

    a. Using any text editor, write the concepts both in the rows and in the columns. Fill in each point.

Concept	A	B	C	D
A	0	5	6	1
B	5	0	3	2
C	6	3	0	4
D	1	2	4	0

    b. Save the data as a text file.

    c. Pathfinder uses two parameters: the q parameter constrains the number of links traversed in paths in the network; the r parameter defines the metric used for computing the distance of paths. If in doubt, the q parameter in the KNOT program should be set to the number of concepts minus one, and r should be set to infinity.

2. Analyze the matrix using the Pathfinder algorithm. Open a data file under Pathfinder and the system automatically does all of the computations. This produces a matrix of related coefficients. The computerized program uses this information to create a spatial layout.

3. Create a spatial layout using the Layout function. Figure 3 shows the output of the Layout function using 14 concepts from a psychology course. Figure 4 shows the output for 24 EW concepts.
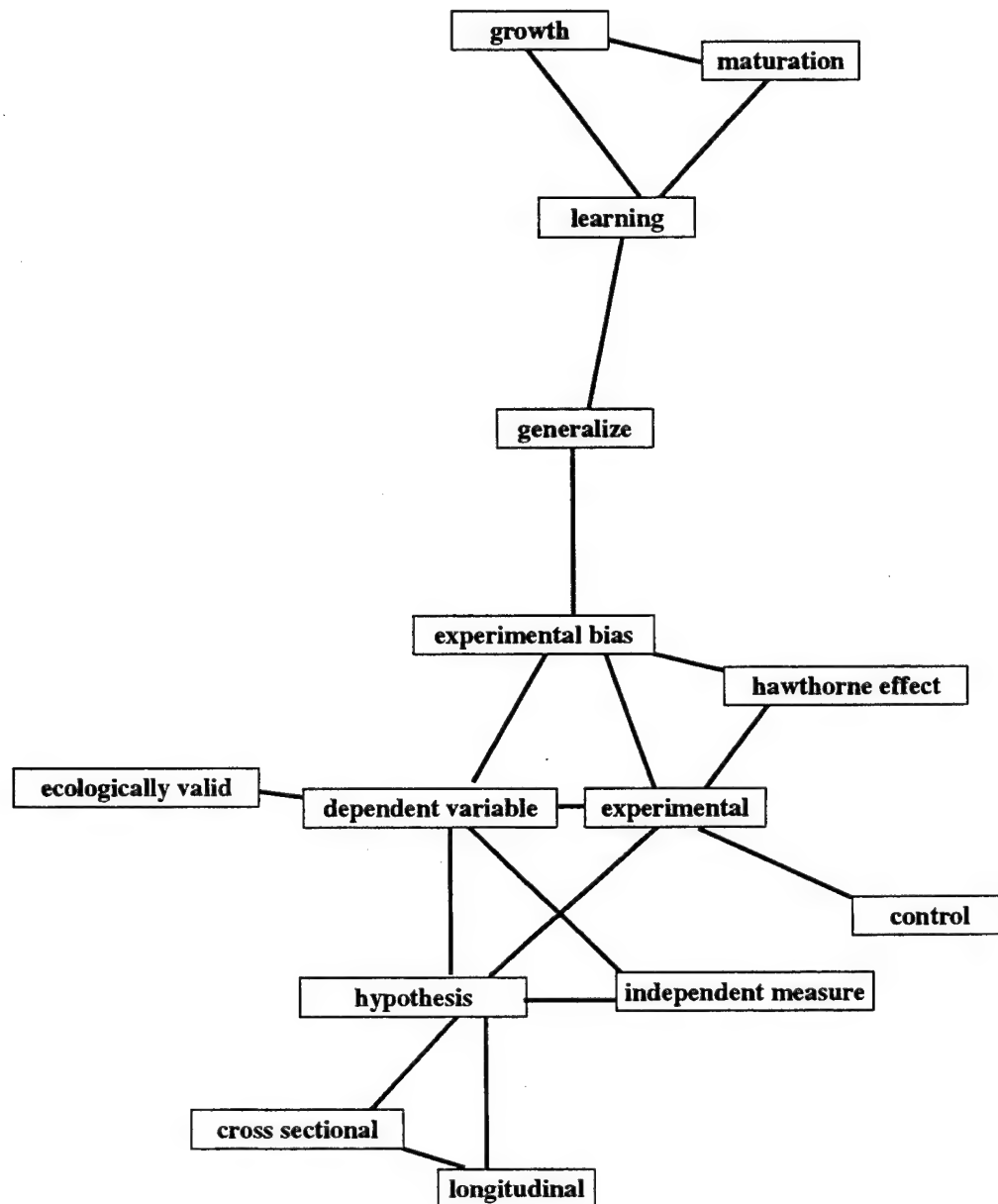
Figure 3. PFNet for psychological concepts.

Figure 4. PFNet for abbreviated EW concepts.
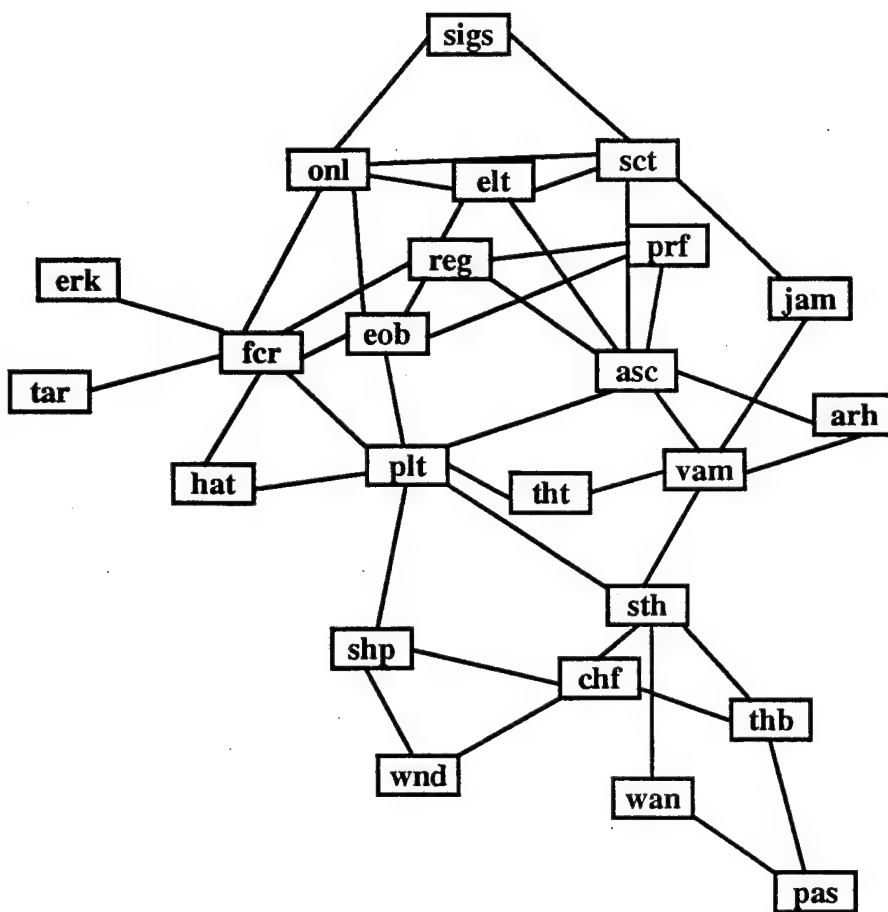
arh - ARH missile	jam - jamming	shp - ship speed
asc - ASC missile characteristics	onl - on-line library	sth - surface threat environment
chf - chaff solution	pas - pass down	tar - target-acquisition-tracking radars
elt - ELINT parameter limits	plt - platforms	thb - threat bearing
eob - electronic order of battle	prf - pulse rate frequency	tht - threat terminology
erk - emergency racket report	reg - rapid evaluation guidelines	vam - vampire report
fcr - fire control radars	sct - scan types	wan - warning status
hat - hostile attach indicators	sigs - signal select	wnd - wind direction

4. If you want to average nets from several respondents, use the Average function that is part of the KNOT program.

5. To compare two nets use the Similarity function. Similarity is determined by the correspondence of links in two networks. The measure is the proportion of all the links in either network that are in both networks.

Training

The interconnection of elements of knowledge has been identified as one of the important components of competent performance (Glaser, 1989). Once these interconnections have been identified, PFNets may be used to design instruction. Output from the PFNet program would indicate which concepts are related to each other and the strength of the relationship. The shorter the line between two concepts, the stronger the relationship. When any of the concepts are first taught, they should be related to other concepts that have been identified as connected in the PFNet.

PFNets may be used to compare the knowledge structures that are present for most experts with those of an individual student or a group of students. Specifically, the Nets would indicate the strength of relationship between two concepts for the expert. If there were no link or a very weak link for the student, it would indicate the need to stress more information and experience to strengthen those two concepts. In addition, the knowledge structures of students can be compared at the start and end of a course to look for changes and to see if the knowledge structures of the students at the end of the course are more similar to those of experts than they were at the beginning of the course.

Conclusions

The methods described here are appropriate for conducting a cognitive task analysis for a complex decision making task. Any of the methods could be used independently or in combination. Development of a task process model is time consuming but is important for obtaining an organizing framework for the design and development of instruction. The information flow model is appropriate for any task invoking teams or individuals who communicate with each other in the performance of the task. An analysis of misconceptions or rules of thumb will help define the boundaries of any rules used in the performance of a task. Structural knowledge analysis involves little effort or time on the part of the task performers but does involve analyst time and the use of a computerized program for its execution.

Recommendations

We recommend that the cognitive task analysis methods described here be used in revising instruction for a complex decision making task. For new instruction, these methods could be used in conjunction with traditional task analysis.

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Appendix A

Critical Incident Interview Guide

Critical Incident Interview Guide

A. *Describe the purpose of the interview*: "We want to learn how you make decisions while working on your job. Please respond accurately and completely and take your time. I would like to use the tape recorder in case I can't write everything down, if that's OK with you. No one outside this research group will hear the tape."

B. Give the interviewees some *paper and a pencil* in case they want to make a diagram.

C. *Start the interview.*

1. Select Incident.

    "I would like you to discuss some difficult decisions or events that occurred while you were performing your job. This could be a situation where an error was likely, or did in fact occur. Let's start with one such event."

2. Obtain unstructured incident account in the form of a time line.

    "Describe the incident from start to completion. I would like to reconstruct the events in the form of a time line that establishes the sequence of each event."

    Repeat the incident back to the interviewee to make sure you have it correct.

3. Decision point identification.

    "Now I would like you to help me identify specific decision points on the time line. A decision point occurs when someone else might have chosen to act differently."

4. Decision point probing.

    For each decision point, use the following probes.

    a. *Errors.* "If an error occurred, what was the error?"

        Hypothetical. "If an error occurred, how should the incident have proceeded?"

        Missing data. "What would have helped you make the decision? What data or information was missing?"

        Error avoidance. "How could the error have been avoided?"

    b. *Cues/Situation Awareness.* "What were you seeing or hearing that caused you to make this particular decision?"

    c. *Comparison to novice* (if interviewing an expert). "How might someone with less experience have responded?"

d. *Knowledge.* "What information did you use in making this decision, and how was it obtained?"

e. *Decision options.*

(1) "What other choices did you consider or were available to you?"
[If none, do not proceed with options.]

List other choices:

(a) Restate first rejected option.
"What was the reason for rejecting it?"

(b) Restate each rejected option and ask the reason for rejecting it.

(2) Classification of the types of options elicited. "Were the options you considered standard or constructed?"

(a) Standard--ones you are commonly taught to consider.

(b) Constructed--created by you or changed from the standard in some way. (If so, "What experience was necessary to generate this option [personal operator experience, special training, etc.]?")

f. *Rule of thumb.* "If a new operator was standing beside you during this incident and asked you what rule (advice) you were following when you made this decision, what would you say?"

5. *Additional incidents.* "Can you recall another incident that was difficult or where an error might likely have occurred?" If so, repeat steps 2-5.

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Appendix B

Example of Questions Used to Complete the Task Process Model

Example of Questions Used to Complete
the Task Process Model

Set (Preparation)

    1. When you start to stand watch, what are you looking for?

Initiating Cues

    2. What do you do when a major alert is heard?

    3. What do you do during a lull when no new emitters are coming up?

Emitter Identification

    4. When an emitter first comes up, what knowledge, sources, or resources do you use in evaluating it? In what order?

    5. Do you use Rapid Evaluation Guidelines? How do you use them? At what point do you use them?

    6. Do you choose to listen to the emitter signal very often? At what point do you listen to the signal?

    7. Do you use the on-line library much? When do you use the on-line library?

    8. If there are two or more missiles on the screen at approximately the same time and the computer system is too slow, what do you do?

    9. What do you do when an unknown emitter appears on the screen?

   10. What do you do when a friendly or neutral emitter appears on the screen?

   11. Do you log friendly emitters? As soon as you recognize them or at a lull?

   12. At what point do you report missile composition?

Information Dissemination

   13. If you are not certain, should you report a suspected missile?

   14. Do you report a missile if you cannot identify it? Or do you assume someone else in the battle group will identify it?

   15. At what point do you report a threat?

   16. At what point do you report a missile to the officer in charge? When do you report a missile over the net?

17. At what point do you report launching countermeasures? To whom do you report?

Countermeasures

18. Under what circumstances does the watch supervisor take over equipment operation?

19. Under what circumstances do you use countermeasures? Describe how you use it.

20. Under what circumstances would you not take countermeasures?

21. If two or more missiles appear close together in time, what countermeasures do you take?

22. What elements do you consider when determining what countermeasures to use?

23. After using countermeasures, how do you determine if the countermeasure has been successful?

24. If a missile is inactive after using countermeasures, do you sequence through to delete the missile from the screen?

Appendix C

Task Process Model for the EW Task

```
                              ┌───────────┐
                              │   START   │
                              │   WATCH   │
                              └─────┬─────┘
                                    │
     ┌──────────┬──────────────────┼──────────────┬───────────────┐
     ▼          ▼                  ▼               ▼               ▼
┌─────────┐ ┌──────────┐ ┌─────────────────┐ ┌──────────┐ ┌──────────────┐
│Consult  │ │ Check    │ │Check Screen For │ │ Check    │ │Gather Info   │
│Summary  │ │Environ-  │ │Location and     │ │Equipment │ │From Other    │
│of       │ │ment      │ │Evaluation of    │ │Set-up    │ │Sources       │
│Threats  │ │Specifi-  │ │Threats          │ │          │ │              │
│in the   │ │cations   │ │                 │ │          │ │              │
│Area     │ │          │ │                 │ │          │ │              │
└────┬────┘ └──────────┘ └─────────────────┘ └──────────┘ └──────────────┘
     │
     ▼
┌───────────────┐
│Integrate      │
│Situation      │
│Information     │
└───────┬───────┘
        │
        ▼
┌──────────────┐              ┌──────────┐
│Listen To,    │◄─────────────│ Update   │◄───────────────────────────┐
│Look For      │              │Situation │                            │
│Emitter Alert │              └──────────┘                            │
└──────┬───────┘                                                      │
       │                                                              │
       ▼                                                              │
    ◇─────◇      No                                                  (A)
   ◇ Emitter ◇──────────┬────────┬────────┬────────┬────────┬────────┘
   ◇ Alert  ◇           ▼        ▼        ▼        ▼        ▼        ▼
    ◇  ?  ◇        ┌────────┐┌────────┐┌────────┐┌────────┐┌──────┐┌────────┐
     ◇───◇         │Verify  ││Identify││Correlate││Check   ││Verify││Antici- │
       │           │Evalu-  ││Unknown ││Emitters ││For     ││Log   ││pate    │
     Yes           │ated    ││Emitters││To       ││Changes ││      ││Threats │
       │           │Emitters││        ││Platforms││In      ││      ││        │
       ▼           └───┬────┘│        ││         ││Emitters││      ││        │
┌────────────┐         └─────┴────────┴────────┴─┴────────┴┴──────┴┴────┬───┘
│Place Cursor│                                                          │
│On Emitter  │◄─────────────────────────────────────────────────────────┘
└──────┬─────┘
       │
       ▼
┌──────────────┐         ┌──────────┐
│Check Emitter │◄───────►│Listen to │
│Parameters    │         │Signal    │
└──────┬───────┘         └──────────┘
       │
       ▼
┌──────────────┐
│Check Computer│
│Evaluation    │
└──────┬───────┘
       │
       ▼
    ◇──────◇    No            ◇──────◇   No    ┌──────────────┐
   ◇  In    ◇─────────────►  ◇ Dense  ◇────────►│Check Emitter │
   ◇Operator's◇             ◇Environ- ◇         │Data Base     │
   ◇ Memory ◇               ◇ment ?  ◇          └──────┬───────┘
    ◇   ?  ◇                  ◇────◇                    │
     ◇──◇                       │                       │
      │                       Yes                       │
     Yes                        │                       │
      │                         ▼                       │
      │                 ┌──────────────┐                │
      │                 │Use Rapid     │                │
      │                 │Evaluation    │                │
      │                 │Guidelines    │                │
      │                 └──────┬───────┘                │
      │    ┌──────────────┐    │                        │
      │◄───│Gather Info   │◄───┴────────────────────────┘
      │    │From Other    │
      │    │Sources       │
      │    └──────────────┘
      ▼
  ┌───────┐
  │ Go To │
  │   B   │
  └───┬───┘
      │
      ▼
 To Next Page
```

C-1

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                    ( B )
                      │
                      ▼
              ┌───────────────┐                    ┌───────────────┐                    ┌──────────────┐
              ╱  Hostile       ╲      Yes           ╱   Missile       ╲      Yes          │  Report to   │
             ╱   Emitter        ╲──────────────────╱       ?           ╲─────────────────│  Officer     │
             ╲      ?           ╱                   ╲                   ╱                  │  In Charge   │
              ╲               ╱                      ╲               ╱                    └──────────────┘
               └──────┬──────┘                        └─────┬──────┘                            │
                      │ No                                  │ No                                │
                      ▼                                     ▼                                    ▼
            ┌──────────────────┐                  ┌───────────────────┐             ┌──────────────────┐
            │ Check Emitter    │       ┌──────────│    Missile        │             │ Consider Missile │
            │ Information As   │       │ Report to │  Guidance,        │             │ Characteristics  │
            │ Time Permits     │       │ Officer   │ Target Tracking   │             └──────────────────┘
            └──────────────────┘       │ In Charge │  or Target        │                      │
                      │                └───────────│ Acquisition       │                      │
                      ▼                   No        ╲  Radar          ╱                       │
            ┌──────────────────┐                     ╲    ?          ╱                        │
            │ ID Emitter       │                       └─────┬──────┘                         │
            │ Carrier          │                             │ Yes                            │
            └──────────────────┘                             ▼                                │
                      │                            ┌───────────────────┐                      │
                      ▼                            │ Report to Officer  │                      │
            ┌──────────────────┐                   │ In Charge          │                      │
            │ Log As Time      │                   └───────────────────┘                      │
            │ Permits          │                             │                                │
            └──────────────────┘                             ▼                                │
                      │                            ┌──────────────┐                           │
                      ▼                            ╱  Counter-     ╲    Yes                    ▼
                  ( Go to                         ╱   Targeting     ╲──────────────────────▶ ( C )
                     A  )                         ╲  Necessary      ╱                          │
                                                   ╲     ?        ╱                           │
                                                    └─────┬──────┘                            │
                                                          │ No                                │
                                                          ▼                                   ▼
                                                ┌──────────────────┐              ┌──────────────────┐
                                                │ ID Emitter Carrier│             │ Determine        │
                                                └──────────────────┘             │ Best Method(s)   │
                                                          │                       │ of Engagement    │
                                                          ▼                       └──────────────────┘
                                                ┌──────────────────┐                      │
                                                │       Log        │                      ▼
                                                └──────────────────┘              ┌──────────────┐
                                                          │                       ╱ Countermeasure╲   No
                                                          ▼                       ╲  Successful    ╱────┐
                                                      ( Go to                      ╲    ?        ╱      │
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                                                                                          │ Yes         │
                                                                                          ▼             │
                                                                                     ( Go To           │
                                                                                        A  )           │
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